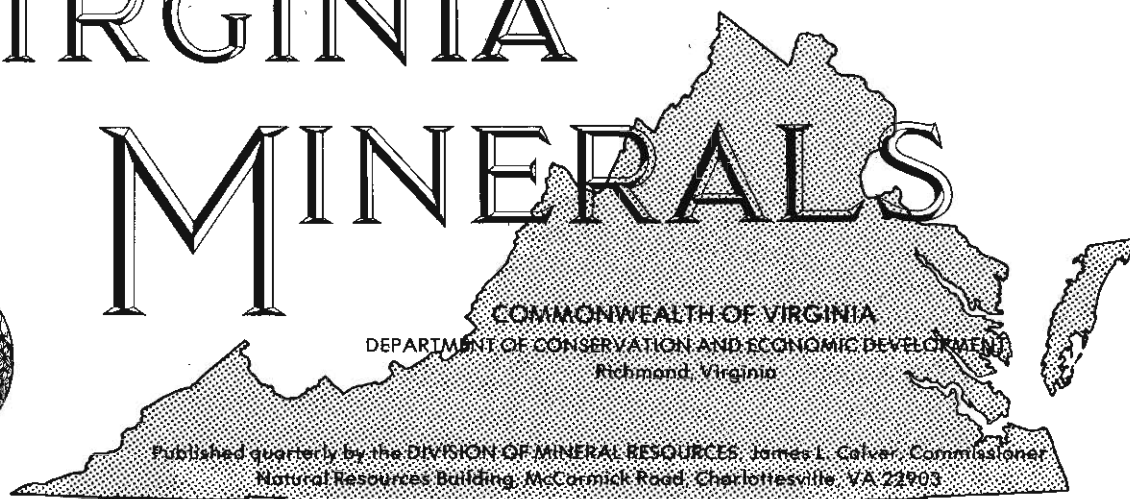


# VIRGINIA MINERALS



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## ON EARTHQUAKES

David K. Lasch

### INTRODUCTION

A comprehensive review of the earthquake history of Virginia has been given by Hopper and Bollinger (1971), Bollinger and Hopper (1972), and Bollinger (1975a). They thoroughly reviewed all available newspapers and journals for accounts or descriptions of local earthquakes. This allowed them to extend their data base back in time for about 200 years. Only a brief summary of their work is included here.

Approximately 143 earthquakes occurred in Virginia from 1774 through 1976. Almost half of these earthquakes have been reported since 1900. The year 1900 is usually considered as the cutoff between preinstrumentally recorded data (that is, the earthquake was felt and then reported to a newspaper) and data which were instrumentally recorded. More observations would have been made or more smaller events noted after the advent of reliable detecting equipment. The improvement of mass communication techniques in more recent times would also tend to increase the number of felt events that were actually reported to the public. Care should be taken to avoid misconstruing the increase in reported events with an actual increase in earthquake activity. The data base is only about 200 years long, which may not be sufficient to allow meaningful statements to be made about recurrence rates.

Virginia contains three earthquake, or seismic, zones (Bollinger, 1973). Of the three zones: northern

Virginia-Maryland, central Virginia, and southern Appalachian, only the central Virginia is wholly within Virginia (Figure 1). The northern Virginia-Maryland and southern Appalachian zones trend northeast-southwest and correlate approximately with the Valley and Ridge and Blue Ridge provinces. The trend of the central Virginia zone is oblique to that of the other two zones. The seismic activity, about 75 earthquakes, of

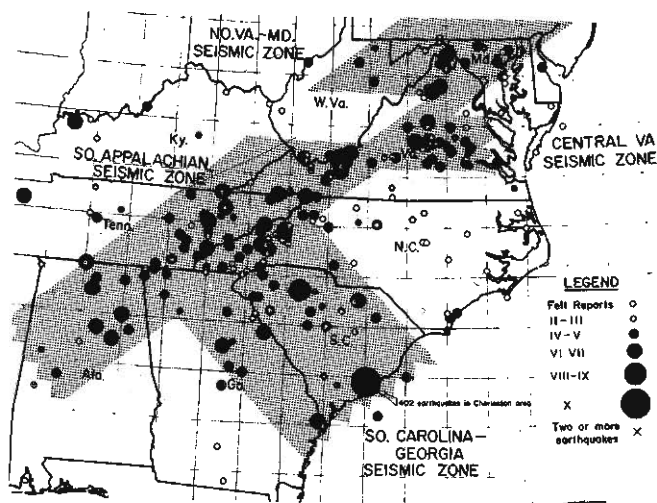


Figure 1. Southern Appalachian seismicity, 1754-1970 (courtesy G. A. Bollinger, Virginia Polytechnic Institute and State University).

this zone is almost entirely within the Piedmont province. It is clearly defined; the historical data indicates that the area to the east, south, and west is relatively inactive seismically (Bollinger, 1975b). It should be noted that the seismic activity within Virginia is oriented both parallel and transverse to the dominantly northeastward-trending structure of the Appalachian Mountains (Bollinger, 1973). Because of this lack of correlation between known earthquake activity and tectonism, considerably more seismic data must be gathered before a detailed correlation between the seismicity and the geology of the region can be made.

One approach to correlating earthquake activity with regional geology is the preparation of isoseismal, or "felt area," maps that are derived from earthquake intensity studies. The "felt area" is that area on the ground upon which the earthquake was either felt or some evidence such as cracked plaster, broken windows, or damaged chimneys, was observed. Felt area patterns for earthquakes studied to date tend to be elongated in the northeasterly-southwesterly Appalachian trend (Bollinger, 1973). Even the events within the central Virginia zone reflect that orientation. Apparently the Appalachian Mountains act as a wave-guide and channel seismic energy along a northeasterly-southwesterly direction.

There have been three large earthquakes in Virginia. The largest had a maximum intensity of VIII (Table 1) and occurred in Giles County on May 31, 1897. The other large earthquakes had maximum intensities of VII and were located near Petersburg, February 21, 1774, and Richmond, December 22, 1875.

The earthquake of February 21, 1774 near Petersburg was the first reported historic seismic event in Virginia. Other earthquakes had occurred before this one but no known references to them have been found. The felt area for this earthquake is estimated to be approximately 58,000 square miles (Hopper and Bollinger, 1971). Very little is known about this earthquake.

The earthquakes of December 22, 1875 and May 31, 1897 have been studied in detail by Bollinger and Hopper (1971). They noted that during the earthquake of 1875, residents of the region extending from Maryland to North Carolina and including all but the southwestern and northern extremes of Virginia felt the effects. They determined the felt area to be about 50,000 square miles. The earthquake of 1897 had a felt area estimated to be at least 280,000 square miles and was felt from Ohio and Pennsylvania to South Carolina and Georgia (Bollinger and Hopper, 1971).

The recorded earthquake history of Virginia can be

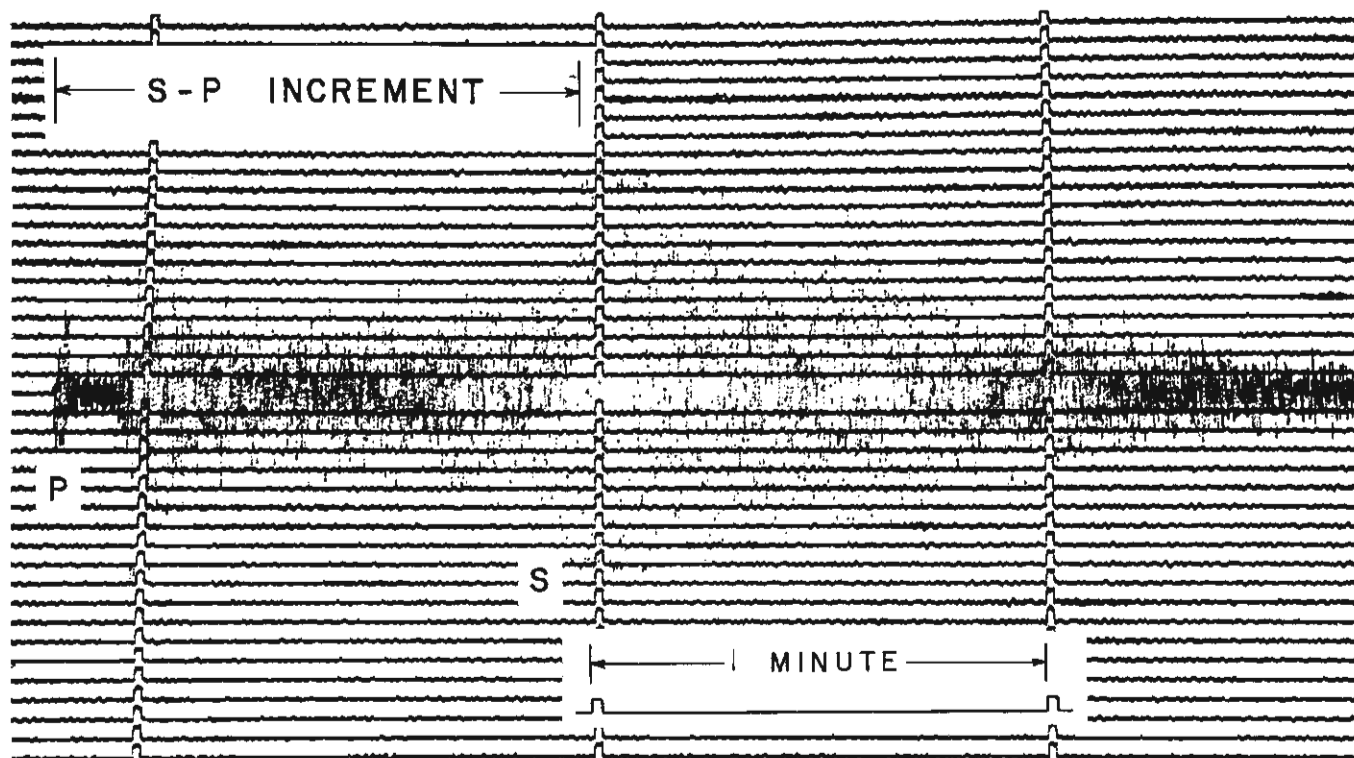


Figure 2. A portion of a vertical-component seismogram showing an earthquake located in Knox County, Kentucky, January 19, 1976, magnitude 4.0 (Richter scale), intensity VI (Modified Mercalli scale).

summarized as being comprised of small events with intensity levels below V but quite persistent in their occurrence over the last 200 years (Bollinger, 1975b).

### EARTHQUAKE-RECORDING EQUIPMENT

Earthquakes, quarry blasts, and other man-made blasts are usually termed "events." The instrument that detects the actual ground displacement due to the passage of an event is referred to as a seismometer. It translates the motion of the ground into an electrical current, or signal, which is then filtered to remove unwanted noise and then amplified so the signal can be recorded in some manner, usually either a photographic process, pen and ink, or heat-sensitive paper. The actual recording, or record, is called a seismogram (Figures 2, 3). The entire system, the seismometer, all

the necessary ancillary electronic equipment, and the recording device, is generally referred to as a seismograph or a seismic station (Figure 3).

In general the displacement of the Earth's surface due to an event will require three dimensions to describe it. That is, the displacement will not be purely vertical or purely horizontal but will be the resultant of some combination of the two (Figure 4). Seismometers have been designed to respond to purely vertical motion or purely horizontal motion. The usual

Table 1. — Modified Mercalli intensity scale of 1931, abridged (modified after Bollinger and Hopper, 1972).

- I. Not felt except by a very few under especially favorable circumstances.
- II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
- III. Felt quite noticeably indoors, especially on upper floors of building, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated.
- IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
- V. Felt by nearly everyone; many awakened. Some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
- VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
- VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
- VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars.
- IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
- X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
- XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
- XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

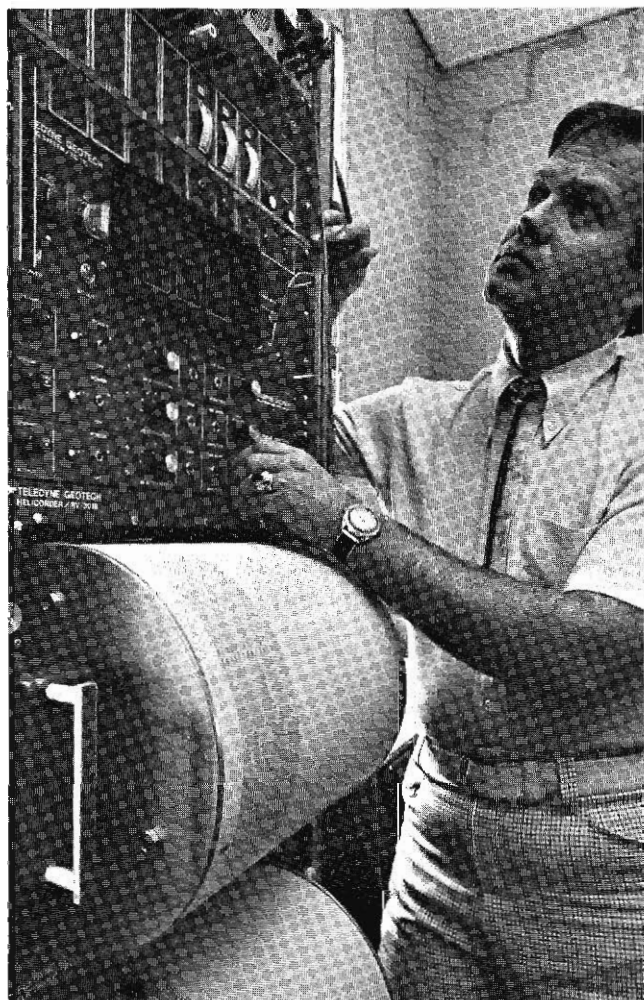


Figure 3. The recording equipment of the seismic station at the Virginia Division of Mineral Resources, Charlottesville.

technique for determining the resultant ground displacement is to install three seismometers: one to record the vertical component and two to record the purely horizontal components of the motion. The two horizontal components are then arranged perpendicular to each other. Usually they are oriented north-south and east-west. Therefore, the three seismometers are perpendicular to each other and are designed to measure only one component of the ground motion. By examining the north-south, east-west, and vertical component seismograms the actual ground motion can be determined.

There are only two basic types of wave propagation through an elastic solid: body waves and surface waves. The distinction between the two wave types is made by the path along which the elastic disturbance propagates. Body waves, as their name implies, travel through the medium or the body. Surface waves are restricted to propagating along, or to be guided by, some type of surface. The most common type of guiding surface for wave propagation is the surface of the Earth. The Earth's surface is referred to as a "free surface" or a "stress-free surface" because the stress due to the elastic disturbance cannot be propagated across it into the atmosphere. It should be pointed out that surfaces other than the Earth's surface may act as a waveguide. Assuming the proper conditions, mainly the necessary density contrast between two adjacent lithologic units, the interface between the two units could serve as a guiding surface for this type of wave. Because some type of guiding surface is required for this type of propagation, surface waves are generally referred to as guided waves. To briefly summarize, body waves do not require a surface or guide to propagate along whereas surface or guided waves do.

The displacement of the Earth's surface during the passage of an event will be in an arbitrary direction, thus requiring the recording of three perpendicular

components of the ground displacement in order to reconstruct the amplitude of the displacement. Seismometers are capable of detecting the usually infinitesimally small ground displacements. The vertical component seismogram will indicate the arrival of the P-wave (the fastest propagating body wave), the SV-wave (a vertically polarized S-wave), and the Rayleigh wave (the slowest surface wave). The arrival of the S-wave (the slowest propagating body wave), but not the SV-wave, and the Love wave (the fastest surface wave) will generally be most obvious on one or both of the two horizontal component seismograms.

When one or more seismometers are installed at a single site the installation can be considered as a one-element array consisting of one or more components. That is, the number of components is equal to the number of seismometers installed. The information gathered from such an arrangement is useful but limited. The limitation will be discussed in the interpretation of the seismic data. To expand the usefulness and accuracy of the data it is first necessary to expand the aperture, or spacing, of the array. That is, more elements, or seismic stations, must be added. With the addition of more elements the array, or network, will cover a particular area. Adding more seismic stations to closely monitor the seismic activity originating within the network will provide more data and also increase the accuracy of the data set.

The minimum number of elements contained in an array would obviously be three. This would allow the location of epicenters (the point on the Earth's surface directly above the focus of an earthquake) by triangulation. In actual practice the minimum number is usually five. This number of elements affords enough data for the standard analysis computer program, HYPO-71, to calculate the epicentral location, a fault plane solution, and the depth of the focus as well as a few statistics which yield a measure of the reliability of the solutions.

The Virginia Division of Mineral Resources operates a short-period (high-frequency) seismic station at Charlottesville. The Division cooperates with the National Earthquake Information Service, Denver, Colorado and the Virginia Tech Earthquake Center, Blacksburg, Virginia by making its data available for the determination of epicenters and magnitudes of earthquakes within Virginia and the eastern United States.

Although the station is intended to closely monitor events within Virginia, earthquakes from all over the world—Turkey, Iran, China, the Philippines, South America, and many other places—have been recorded. Detonations from the Nuclear Test Site in Nevada have also been recorded.

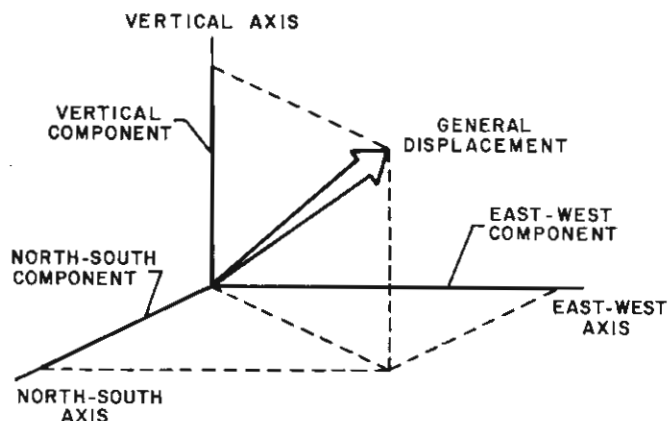


Figure 4. A general displacement and its three components.

There are four other seismic stations located in Virginia: Fredericksburg Observatory, Corbin; Madison College, Harrisonburg; Virginia Polytechnic Institute and State University, Blacksburg; and Washington and Lee University, Lexington.

#### ANALYSIS OF A SEISMOGRAM

A seismogram is a visual record of the history of a particular component of the particle displacement recorded at a specific location on the Earth's surface, that is, at the location of the seismometer vault. When analysing a seismogram it is important to first determine the length of time elapsed between any two consecutive time marks. The standard spacing between consecutive time marks is usually 60 millimeters (Figure 2) and would require a recording drum rotation of 1 millimeter per second. With this recording rate it is possible to measure the time of arrival of a particular phase to the nearest 0.1 mm, that is, to 0.1 second. With the present knowledge of the depths to the various seismic discontinuities within the Earth as well as the uncertainty in the speed with which body and surface waves propagate through the various rock types, it does not necessitate being able to determine arrival times with more accuracy than 0.1 second.

To illustrate the method of locating an event, a simple graphical method will be used as opposed to the rigorous analytic approach yielded by the computer program HYPO-71. In using either technique it is first assumed that the number of layers composing the model as well as their thicknesses and the speed of propagation of both the P- and S-waves in the various layers are known. From this data a "travel-time" plot can be constructed. A travel-time plot is simply a graph showing the relationship between the time of arrival of all P, S, L, and R phases and the distance from the event. Recall that a seismogram records the difference in time of arrival of the various phases (Figure 2). The difference in arrival time (the P- and S-waves are used) can then be related to the distance from the event through the use of the travel-time plot. A circle whose radius is equal to the distance corresponding to the observed time increment between the P- and S-waves can then be drawn about the seismometer site. It can now be seen that a single station is inadequate to locate an event. That is, the event could have occurred anywhere along the circle. A single point on the circle could be located with the cooperation of two more seismic stations. That is, the intersection of three circles would uniquely determine the location of the event. It is interesting to note that the system of equations solved by the computer program is analogous to the actual plotting of the circles to obtain the intersection point.

It is important to realize that there are two scales used in describing the size and the effects of an earthquake. The first is known as the Richter *magnitude* scale and is named after the person who devised it, C.F. Richter. The second scale is referred to as the Modified Mercalli *intensity* scale which was proposed by G. Mercalli (Table 1).

The Richter magnitude is a measure of the size of the earthquake. It is calculated from a formula once the distance from the seismometer site to the earthquake, the magnification of the system, and the amplitude and period of a specific phase have been determined. It is a quantitative measure. The Richter magnitude scale is logarithmic; for example, a magnitude 7 earthquake is 10 times larger than a magnitude 6. Also, the Richter scale is open-ended: it has no upper limit.

The Modified Mercalli intensity scale is used to describe the physical effects of the earthquake. Its range extends from I, not felt, to XII, total destruction. It should be pointed out that an earthquake will generally have a whole range of intensity values, that is, ranging from "not felt" up to some Roman numeral describing the effects in the area closest to the earthquake, but only one magnitude value. The intensity values are usually plotted on a map and then contoured. This yields an isoseismal or "felt area" map, which can sometimes be related to the local geology. Finally, the intensity values are obtained by distributing Earthquake Report questionnaires in the vicinity of the earthquake.

#### OBJECTIVE OF EARTHQUAKE SEISMOLOGY

The objective of the earthquake monitoring program of the Virginia Division of Mineral Resources is to determine the location and magnitude of earthquakes occurring within the State.

Very little quantitative data have been accumulated for Virginia and the East Coast of the United States. Approximately 200 years of historical data generally noting only the occurrence of an earthquake have been collected for most of the eastern United States. It is still quite uncertain whether this period of time is long enough to permit meaningful statements to be made pertaining to the periodicity or recurrence rates of earthquakes for the area.

In order to formulate a basis to allow earthquake predictions to be made for Virginia and the East Coast of the United States much more data must be obtained. More quantitative information pertaining to the two most useful parameters: focal depth and a focal-plane solution for each earthquake must be gathered. With the accumulation of more quantitative data it should be possible in the future to predict earthquakes.

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THE MINERAL INDUSTRY OF VIRGINIA IN 1975<sup>1</sup>

## ADVANCE SUMMARY

Virginia's total mineral production in 1975 was valued at \$1,264,800,000, an increase of \$208,300,000 or 20 percent above that of 1974. This was the thirteenth consecutive year that the value of mineral production has shown an increase and was primarily due to increased output and value of bituminous coal (Table 2).

Bituminous coal, Virginia's leading mineral commodity, showed an increase of 3 percent in output and 27 percent in value. It comprised 86 percent of the total mineral production value of the Commonwealth. Other leading mineral commodities in descending order of value were stone, cement (masonry and portland), sand and gravel, and lime. These five commodities

accounted for 98 percent of Virginia's total mineral production value.

Petroleum value showed an increase of 35 percent over that of 1974. Natural gas output declined 5 percent and value 4 percent below that of the previous year.

Stone decreased 20 percent in tonnage and 12 percent in value; sand and gravel decreased 31 percent and 15 percent; clays decreased 58 percent and 56 percent; lime decreased 21 percent in output but increased 7 percent in value; aplite decreased 4 percent in tonnage but increased 16 percent in value; kyanite decreased 9 percent and 7 percent; soapstone decreased 7 percent and 27 percent; and gypsum suffered a substantial decline in both output and value.

Zinc production declined 12 percent and value 4 percent; lead decreased 18 percent in output and 22 percent in value. A small amount of silver was recovered from the smelting of zinc and lead.

<sup>1</sup>Prepared in the U.S. Bureau of Mines Liaison Office—North Carolina and Virginia, Raleigh, NC under a cooperative agreement between the Bureau and the Virginia Division of Mineral Resources.

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THE MINERAL INDUSTRY IN VIRGINIA IN 1976<sup>1</sup>

## PRELIMINARY DATA

Preliminary information shows that the total value of mineral production in Virginia in 1976 was \$1,457,916,000 according to estimates by the U. S.

Bureau of Mines (Table 2). This was the fourteenth consecutive year that mineral values have increased. Of the total mineral value approximately 87 percent was contributed by fuels, 12 percent by nonmetals, and 1 percent by metals.

<sup>1</sup>Prepared in the U.S. Bureau of Mines Liaison Office—North Carolina and Virginia, Raleigh, NC under a cooperative agreement between the Bureau and the Virginia Division of Mineral Resources.

The estimated production of bituminous coal increased 10 percent to approximately 39,000,000 tons



and output value increased from \$1,084,459,000 in 1975 to an estimated \$1,268,000,000 or 17 percent in 1976.

Stone, sand, and gravel decreased in output and value; clay, lime, cement, gypsum, kyanite, and

soapstone increased in both output and value.

Zinc and lead decreased considerably in output and value. However, secondary iron ore recovery was reported for the first time in many years.

Table 2. — Mineral production in Virginia.<sup>1</sup>

Mineral	1974		1975		<sup>2</sup> 1976	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Clays . . . . . thousand short tons	1,957	\$ 2,614	819	\$ 1,152	818	\$ 1,193
Coal (bituminous) . . . . . do . . . . .	34,326	856,099	<sup>3</sup> 35,510	<sup>3</sup> 1,084,459	39,000	1,268,000
Gem stones . . . . .	NA	13	NA	13	NA	10
Lead (recoverable content of ores, etc.) . . . . . short tons	3,106	1,398	2,551	1,097	1,875	866
Lime . . . . . thousand short tons	895	18,929	705	20,192	914	26,623
Natural gas . . . . . million cubic feet	7,096	3,619	6,723	3,462	6,369	3,312
Petroleum (crude) . . . . . thousand 42-gallon barrels	3	W	3	W	NA	NA
Sand and gravel . . . . . thousand short tons	14,314	29,270	9,895	24,776	9,400	23,537
Stone . . . . . do . . . . .	44,176	95,988	35,384	84,204	33,630	83,971
Zinc (recoverable content of ores, etc.) . . . . . short tons	17,195	12,346	15,151	11,818	11,290	8,355
Value of items that cannot be disclosed:						
Aplite, cement, gypsum, iron ore (1976), kyanite, silver						
(1975-76), soapstone, and values indicated by symbol W. . . . .	—	<sup>4</sup> 36,293	—	33,673	—	41,049
Total . . . . .	—	<sup>4</sup> 1,056,569	—	<sup>3</sup> 1,264,846	—	1,456,916
NA Not available. W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."						

<sup>1</sup> Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

<sup>2</sup> Preliminary data; subject to revision.

<sup>3</sup> Revised from value given in *Virginia Minerals*, vol. 22, no. 1, p. 2, February 1976.

<sup>4</sup> Revised from value given in *Virginia Minerals*, vol. 22, no. 1, p. 1, February 1976.

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## AN UNUSUAL OCTAHEDRAL FLUORITE, STILBITE, LAUMONTITE, CALCITE, AND QUARTZ ASSEMBLAGE IN DANVILLE, VIRGINIA

Donald R. Privett<sup>1</sup>

### INTRODUCTION

This article reports the occurrence, provides a description, and suggests the origin of a fluorite, stilbite, laumontite, calcite, and quartz assemblage exposed in Danville, Virginia. The minerals are in fractures in a vertical cut, 5 to 6 m high and 40 m long, located behind the Riverside Shopping Center off U. S. Highway 58W.

The rocks in the area are medium-grained granite and hornblende gneisses. The gneisses are composed of

microcline, plagioclase, quartz, hornblende, and biotite. The rocks are jointed, and in some areas brecciated. In the larger fractures the gneiss is completely chloritized, and in narrow fractures the plagioclase is replaced by laumontite 1 to 2 cm away from a fracture. Areas of laumontization are easily detected by pink color imparted to laumontized plagioclase. The minerals were identified by study of crushed grains in index oils and study in thin sections.

### MINERALOGY

Secondary minerals are present in four distinct areas of the exposure, each one somewhat different in mineralogy and mode of occurrence. Narrow fracture-

<sup>1</sup>Duke Power Company, Charlotte, NC.

filling veinlets, druses, and replacement zones are present. Stilbite is the most abundant and is the only mineral found in each of the four areas. Each occurrence is described and presented in the order of the abundance of minerals in the outcrop.

1. The most widespread and unusual minerals were found in a large druse in a vertical quartz vein, 5 cm wide and 4 to 6 m long. The druse probably formed in the area where the vein traversed a breccia zone. In an area 1 m long the vein opened up to 20 cm wide. At the time of discovery the druse, which was filled with a plastic clay, could be probed arm's length (60 to 70 cm) and extended beyond.

Samples taken from both sides of the druse contained euhedral octahedral fluorite, most 4 to 8 mm long but some up to 1.5 cm, crystallized on the gneiss. The fluorite is covered by a thin layer of white translucent quartz crystals upon which is crystallized interpenetrating and individual white translucent stilbite crystals (4 to 5 mm). The stilbite is partly covered by tiny specks of black hematite. Fragments of

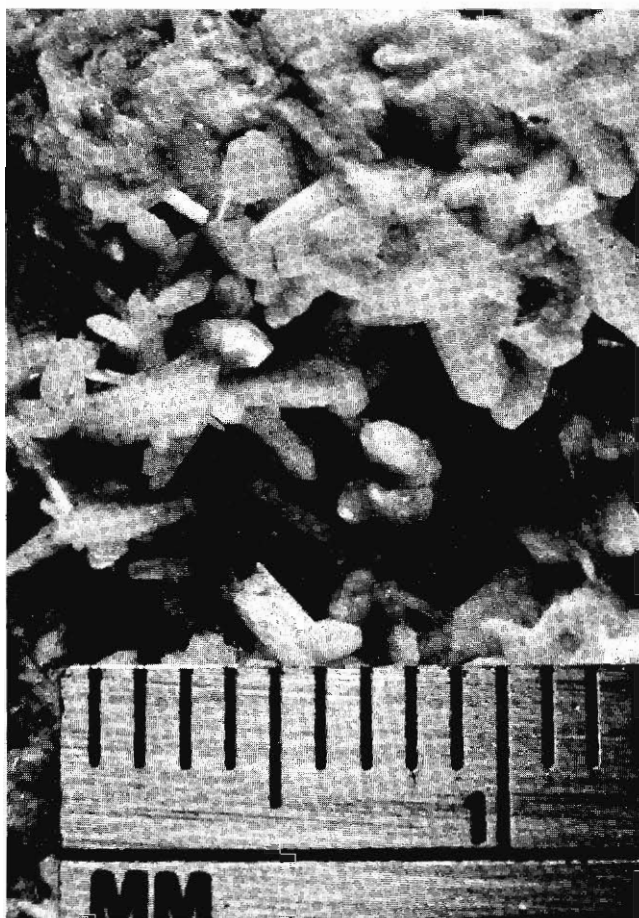


Figure 5. Clusters of interpenetrating euhedral stilbite crystals, Riverside Shopping Center, Danville.

gneiss, 6 to 12 cm wide, that had broken off from the wall and are covered on all but one side by euhedral fluorite, quartz, and stilbite were pulled from the mud that filled the druse, thus showing that brecciation occurred prior to the crystallization of secondary minerals. The stilbite crystals appear to be unusual doubly terminated, single crystals (Figure 5); however, microscopic observation reveals that they are sector twinned. The fluorite is pale blue-green to light purple and is color zoned from light center to darker peripheries. It is always present on the gneiss as interpenetrating octahedrons, 0.2 mm to 1.5 cm across. Octahedral fluorite is rare and crystallizes at higher temperatures (200-400° C) than cubic fluorite which develops below 170°C (Twenhofel, 1947).

2. Replacement and fracture-filling stilbites are present in vertical fractures, 8 to 10 cm wide, in a highly chloritized gneiss. The rock, soft and crumbly, is composed of 70 percent interpenetrating euhedral to subhedral yellowish-white stilbite sheaves and parallel clusters.

In a few samples small laumontite crystals cover a portion of the stilbite. Thin-section examination reveals that the stilbite contains inclusions of chlorite.

3. Vein-filling interpenetrating "bow tie"-shaped sheaves of light-brown stilbite, 0.8 to 1.5 cm long, cover grayish-blue quartz crystals (1 to 1.5 cm). Quartz displays parallel crystallization perpendicular to the vein margin. The stilbite, having an irregular distribution, varies from a few scattered crystals to a dense interpenetrating aggregate completely covering the quartz (Figure 6).

4. Stilbite also occurs in a 2 cm wide vein which was explored for approximately 0.6 m. Translucent rhombohedral calcite is partly covered by small (1 to 2 mm) laumontite crystals. Attractive light-yellow stilbite sheaves (1.5 to 2 cm) and interpenetrating aggregates project outward from the vein margin covering most of the calcite and laumontite. Small rock fragments are completely covered by calcite, laumontite, and thin stilbite.

## SUMMARY AND CONCLUSIONS

Calcium- and fluorine-rich hydrothermal solutions permeated brecciated and jointed granite and hornblende gneiss; adjacent to joints, solutions laumontized and chloritized the gneiss. The extensively chloritized gneiss was replaced by light-brown stilbite sheaves. Octahedral fluorite, quartz, and doubly terminated, zoned stilbite crystals fill veins. Laumontite and calcite crystallized in one fracture.



Synthesis of laumontite (Liou, 1971) has shown that the stability limits vary with CO<sub>2</sub> and H<sub>2</sub>O pressure. When CO<sub>2</sub> is present, it lowers the temperature and permits Ca to be fixed in a carbonate phase. The presence of calcite suggests that CO<sub>2</sub> pressures were at least 0.2 total pressure. Also, solutions probably crystallized under low pressure (0.5 to 1.0 kb). It is suggested that temperature of laumontization was about 205 to 250° C. The presence of abundant octahedral fluorite which forms above 170° C and in the range 200 to 400° C also helps to establish temperatures of crystallization in the range 200 to 250° C.

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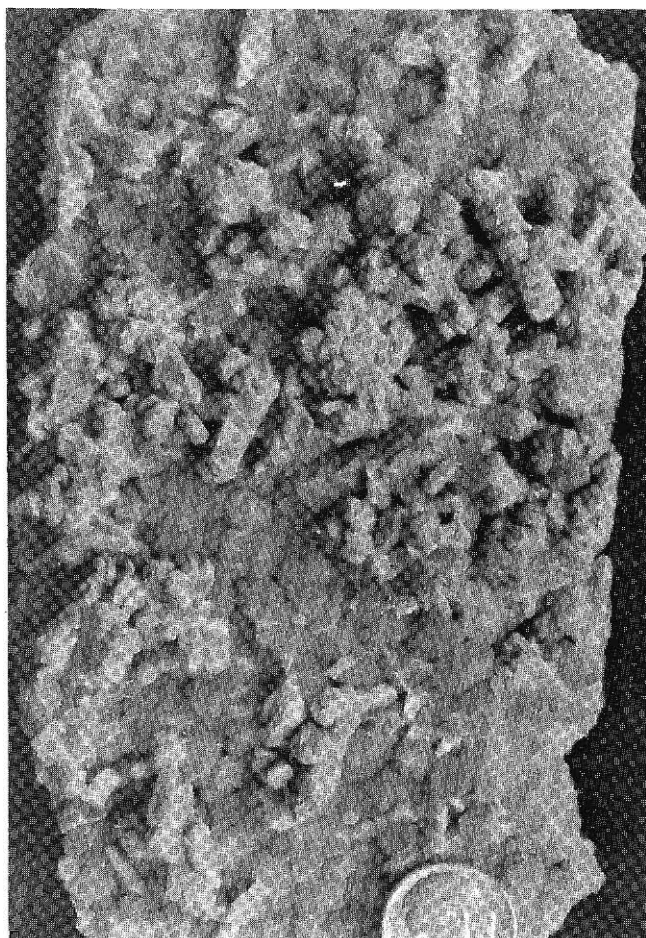


Figure 6. Euhedral brown stilbite crystals on quartz, Riverside Shopping Center, Danville.



## NEW TOPOGRAPHIC MAP PRODUCTS

Warren County is now depicted on a 1:50,000-scale (1 inch equals approximately 0.8 mile), multicolor topographic map which measures 30 x 31 inches. Roads, buildings, forests, hills, towns, and streams are shown in color and by symbols. The Shenandoah National Park outline and Skyline Drive are outlined in color. The setting of Front Royal at the confluence of the North and South forks of the Shenandoah River is graphically depicted. The route of Interstate Highway 66 is shown. Three grid systems for referencing points of interest are available: latitude and longitude in degrees, Universal Transverse Mercator in meters, and Virginia coordinate system in feet.

A unique product to show wetlands areas is now available as an orthophoto map for the Wachapreague quadrangle. This is a multicolor topographic map

which has a photographic base for the wetlands and offshore islands. Tidal channels, coves, and bays are shown. Different types of vegetation can be interpreted. Hunters and fishermen will find this useful in planning future trips to this portion of the Eastern Shore. This orthophoto map and six more in progress for the Dismal Swamp area are the result of another user pilot program.

These products can be purchased from the Virginia Division of Mineral Resources, P. O. Box 3667, Charlottesville, VA 22903 as follows: Warren County map \$2.08 (includes \$0.08 State sales tax); Wachapreague orthophoto map \$1.30 (includes \$0.05 State sales tax). For unfolded copies add \$2.00 for each order of ten or fewer maps.

## NEW PUBLICATIONS

(Available from the Division of Mineral Resources, Box 3667, Charlottesville, VA 22903; State sales tax is applicable only to Virginia addressees.)

LIST OF PUBLICATIONS (1977), 39 p. No charge.

Report of Investigations 45. GEOLOGY OF THE STRASBURG AND TOMS BROOK QUADRANGLES, VIRGINIA, by Eugene K. Rader and Thomas H. Biggs; 104 p., 4 maps in color, 23 figs., 9 tables, 1976. Price: \$7.50 plus \$0.30 State sales tax, total \$7.80.

The Strasburg and Toms Brook 7.5-minute quadrangles are located in Shenandoah and Warren counties, northern Virginia, in the Valley and Ridge physiographic province. The bedrock ranges in age from Early Cambrian (Waynesboro Formation) through Middle Devonian (Mahantango Formation). The Paleozoic rocks are assigned to 28 formations and 23 mappable units. Additionally, Cenozoic sediments consisting of terrace deposits, talus deposits, alluvial fans, and flood-plain deposits are mapped. Also, one peridotite dike of unknown age is mapped.

The report includes four maps in color at the scale of 1:24,000 (1 inch equals approximately 0.4 mile). Two geologic maps show surface geologic units, mainly bedrock. Two environmental maps delineate units with similar properties of residuum and bedrock that could have similar responses to human occupation.

The major structural features consist of the Massanutten synclinorium and North Mountain fault. East of Massanutten Mountain the bedrock has a steep dip and locally the east limbs of synclines and west limbs of anticlines are overturned. The North Mountain fault has an easterly dip. Four large detached footwall slices are exposed along the North Mountain fault. The major fold axes trend to the northeast along the general strike of the formational outcrops. The strongest joint direction is N. 40° W. Two generations of southeastward-dipping cleavage pervade the less competent rock units.

Impure and high-calcium limestone and crushed and broken stone are produced. Iron and manganese ores have been mined in the past. Limestone, dolomite, sandstone, and shale are available as raw materials for many purposes.

Although the geologic formations present have little primary permeability, secondary permeability in the form of fractures and solution openings are sufficiently well developed to contain small to moderate supplies of ground water in most portions of the two quadrangles. Wells in the clastic rocks are the shallowest and have

the fewest failures, and wells in the carbonate rocks have the greatest range in depth and yield. Rock units that contain both lithologies furnish the smallest quantities of water from wells of moderate depths.

Data for land-use decisions is provided by environmental geology information obtained from geological characteristics such as lithology, slope stability, erodibility, rockfall areas, and sinkholes. Reference to soils and land-use potential is made.

Mineral Resources Report 13. CLAY-MATERIAL RESOURCES IN VIRGINIA, by Palmer C. Sweet; 56 p., 1 map, 1976. Price: \$3.00 plus \$0.12 State sales tax, total \$3.12.

This report summarizes the location and potential uses of 485 samples of clay materials from Virginia that are suitable for making ceramic or nonceramic products. The localities are plotted in color on a map of the State at a scale of 1:1,000,000 (1 inch equals approximately 16 miles). The samples are listed by their repository numbers and counties under product headings (such as brick, sewer pipe, tile) and by repository numbers and potential uses under county/city headings. Most of the test results of the samples were reported in Mineral Resources Reports 2, 5, 6, 8, and 12 of the Division of Mineral Resources. However, results for 32 samples are published for the first time.

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## ADDITIONS TO STAFF

Mr. Robert G. Piepul joined the Division staff on December 16, 1976 and is involved in the geologic-mapping program in the Piedmont. He attended Holy Cross College in Worcester, Massachusetts where he received his B.A. in mathematics in 1970. He received his M.S. in geology from the University of Massachusetts in 1975. Mr. Piepul was previously employed with Geotechnical Engineers, Inc., Boston, and the New York State Geological Survey.

Mr. Gerald P. Wilkes joined the Division staff on January 3, 1977 and will assist in the economic-geology section. He received his B.S. in geology from Ashland College (Ohio) in 1974. Previously he was employed by the Wyoming Geological Survey and as a staff coal geologist for the Public Service Company of Oklahoma in Denver, Colorado.

## RADIOACTIVITY SURVEY OF ROCKS IN CENTRAL VIRGINIA

An aeroradioactivity survey that covers 2,280 square miles in central Virginia has been released by the Virginia Division of Mineral Resources. Information is illustrated on all or portions of the following 15-minute quadrangle maps, scale 1:62,500 (Figure 7): Appomattox, Buckingham, Charlottesville, Covesville, Lovingsboro, Madison (all except the northwestern quarter), Scottsville, Shipman, Stony Man (eastern half), University (all except the northwestern quarter), and Waynesboro (southern half). These quadrangles cover parts of Albemarle, Amherst, Appomattox, Augusta, Buckingham, Campbell, Fluvanna, Greene, Louisa, Madison, Orange, Page, and Rappahannock counties.

As a continuing program to provide airborne radiometric data this survey accomplished in 1976 is a westward extension of work completed in 1975 for east-central Virginia. The survey was flown at 500 feet above terrain in an east-west direction with flight lines one-half mile apart. A gamma-ray spectrometer was utilized to record the total counts per second as well as the individual responses of potassium, thorium, and uranium. Radioactivity maps are very useful in determining possible occurrences of uranium. The results procured from radioactivity surveys are especially useful in geologic mapping.

The contour maps (total-count field with major radioactive elements shown), which are on open file in the Division's library at Charlottesville, are available for reference use.

These maps at a scale of 1:62,500 are available as ozalid copies for \$5.20 (includes \$.20 State sales tax) each from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903. An ozalid composite copy of the total survey at the scale of 1:250,000 is available for \$10.40 (includes \$0.40 State sales tax).

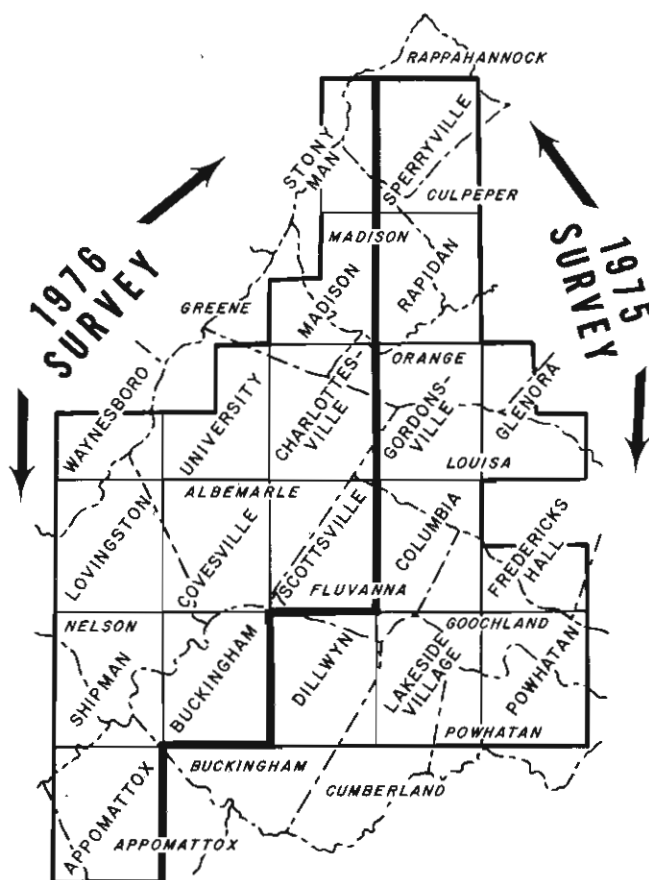


Figure 7. Aeroradioactivity surveys by the Virginia Division of Mineral Resources.

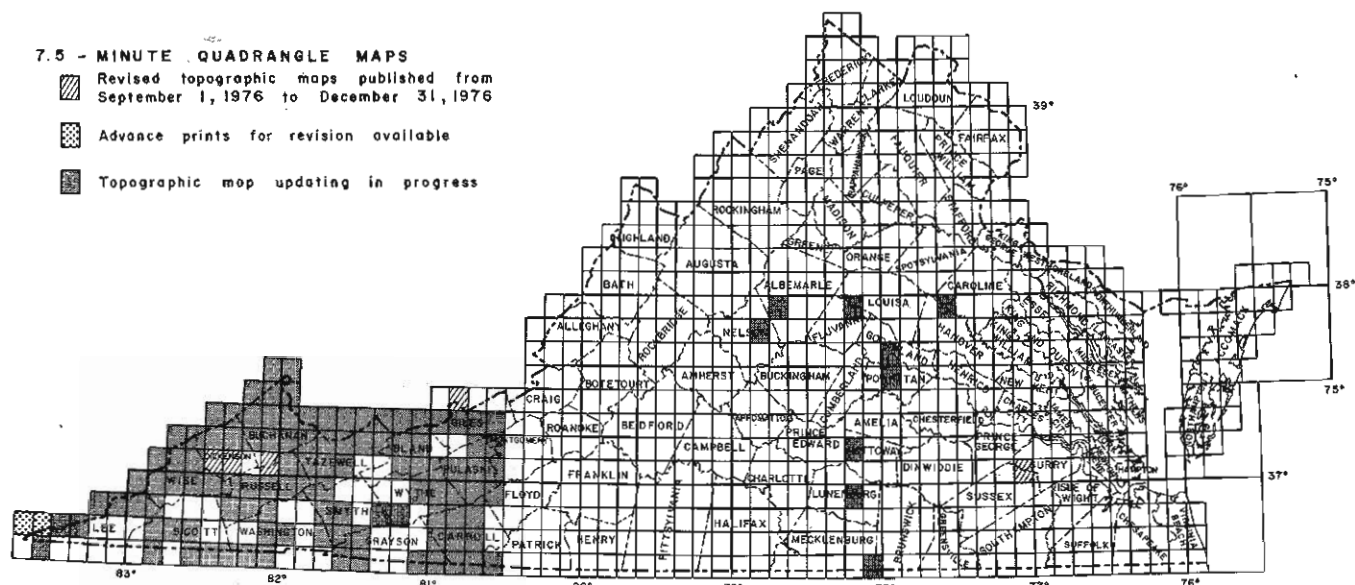
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## TOPOGRAPHIC MAPS



Revised 7.5-minute quadrangle maps published from September 1 to December 31, 1976:

Revised Maps		Advance Prints for Revision
Big A Mountain	Peterstown	Middlesboro North
Caney Ridge	Waverly	Varilla
Nora		

### ADVANCE PRINTS

Advance prints are available at \$1.25 each from the Eastern Mapping Center, Topographic Division, U. S. Geological Survey, Reston, Virginia 22092.

### PUBLISHED TOPOGRAPHIC MAPS

Total State coverage completed; index is available free. Updated photorevised maps, on which recent cultural changes are indicated, are now available for certain areas of industrial, residential, or commercial growth. Published maps for all of Virginia are available at \$1.25 each (plus 4 percent State sales tax for Virginia residents) from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, Virginia 22903.